# LASER GUIDED DISPLAY DEVICE

## BACKGROUND OF THE INVENTION

### Field of the Invention

The invention relates to a laser beam, which scans a display screen comprised of a pixel array of photocells or photo diodes each connected to LED's in the presence of an electric field. The laser's intensity on each photocell produces the desired intensity of LED illumination for that pixel. With a quantum efficiency greater than one, it is possible to create a RGB color display screen activated by a scanning laser. Conventional photodiodes and avalanche photodiodes may all be used in converting the laser's intensity into a current, which is amplified to drive each LED on the display screen.

## PRIOR ART

Prior Art of the invention would involve projection type displays vastly different from the present invention, as these do not utilize a scanning laser to energize pixels on the display screen. Other prior art would include active displays, which again do not utilize a scanning laser to energize pixels on the display screen.

## SUMMARY OF THE INVENTION

The present invention relates to a display device, capable of a very large screen size, utilizing a scanning laser to drive the display elements. The heart of the invention lies in the composition of each picture element or pixel on a display screen. Pixels are arranged in a matrix array on the display screen such that the laser starts scanning the display screen from one corner, moving across horizontally scanning each line on the display screen. All pixels on the display screen are scanned once per frame period, with the intensity and duration of the laser's beam on each pixel variable, in order to produce a variable depth of color on the display.

Each pixel is comprised of Red (R), Green (G), and Blue (B) Light Emitting Diodes (LEDs), with each color LED connected to a photocell or photodiode in the presence of an applied electric field. The laser's beam is directed at selected photodiodes thus generating electricity in the form of electron-hole pairs which is directed to the connected LEDs of different colors, producing a color display output. The intensity and duration of the laser's beam on each photodiode is proportional to the LED's light output. Hence, by varying the laser's intensity on each photodiode connected to each red, green and blue LED of each pixel, it is possible to produce a true color display.

In another embodiment of the invention, a transistor is utilized comprising a photocell and LED combination. At one end the n-p barrier is highly reversed biased and this assists more electrons migrating across or in the avalanche effect as a result of the applied electric field. Hence, this portion of the transistor acts as a photocell with the opposite end highly forward biased at the p-n barrier, acting as an LED attracting more electrons flowing to it, thus enhancing the current flow. As the scanning laser's light

particles or photons strike the photocell region near the barrier, it can strike an atom in the crystal lattice and dislodge an electron. In this way a hole-electron pair is generated which will then migrate under the action of the electric field across the p-n barriers, and recombine with other electrons and holes to generate a light output from the LED. With the applied electric field in the region of the reverse biased n-p barrier, a photo-generated hole or electron can collide with adjacent electron-bonding atoms, breaking the bond, and creating an electron-hole pair further causing an avalanche of carriers due to the electric field, increasing the current flow to the LED producing a high intensity output.

In a further embodiment, the electric field can be manipulated to control the on-off cycles of the display screen. With the electric field applied, the laser is turned on then off for a short duration, during which time a charge is built up in the photocell region. This produces a steady flow of current, which illuminates the LED's, whereby turning off the electric field shuts off the LED's to complete a single frame of the display. At the end of every frame, the electric field is shut off for every pixel, then turned back on prior to the scanning laser passing over each photodiode for the subsequent frame. Once the electric field is turned off the LED's output is also turned off.

In another embodiment of the invention, the electric field is manipulated to turn the LED's on and off for each frame period, utilizing a memory effect within the photocell region of the device. As the laser scans each photocell there is a charge buildup and electron-hole pairs move in all directions away from and towards the n-p barrier. The movement of these electron-hole pairs is of sufficient energy to keep them in motion for the duration the external electric field is turned off, hence creating a memory effect. Once the electric field is applied, the electron-hole pairs accelerate

and migrate across the n-p barrier with sufficient energy creating a current flow, thus turning on the LED's to maximum illumination. Cutting off the electric field would reduce the quantum efficiency of the device, turning off the LED's thus ending that particular frame.

## BRIEF DESCRIPTION OF THE DRAWINGS

The invention is described in more detail below with respect to an illustrative embodiment shown in the accompanying drawings in which:

**Fig. 1** illustrates the pixels on the display screen in accordance with the present invention.

**Fig. 2** illustrates a scanning laser applied to the display screen in accordance with the present invention.

**Fig. 3** illustrates the scanning laser directed to a pixel on the screen in accordance with the present invention.

**Fig. 4** illustrates the layout of pixels on the screen in accordance with one embodiment of the present invention.

**Fig. 5** illustrates a LED-photodiode combination in accordance with the present invention.

**Fig. 6** illustrates the mobility of electron-hole pairs in accordance with the present invention.

**Fig. 7** is a graphical representation of the on-off cycles of the scanning laser and the applied electric field, in accordance with one embodiment of the present invention.

**Fig. 8** is a graphical representation of the on-off cycles of the scanning laser and the applied electric field, in accordance with another embodiment of the present invention.

**Fig. 9** illustrates the laser addressing all pixels on the display screen multiple times per frame period.

**Fig. 10** illustrates the display screen comprised of a single color monolithic construction with an overlaying red, green and blue phosphor pattern.

**Fig. 11** illustrates the generation of carriers and light to produce an output on the display screen.

**Fig. 12** illustrates the effect of the LED output by shutting off the electric field.

**Fig. 13** illustrates the grounding or shorting electrodes to remove capacitance in accordance with one embodiment of the present invention.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

To facilitate description, any numeral identifying an element in one figure will represent the same element in any other figure.

The principal embodiment of the present invention aims to provide a display device, capable of a very large screen size, activated by a scanning laser. With reference to **Fig. 1**, the heart of the invention lies in the composition of each picture element or pixel **1** on a display screen **4**. With further reference to **Fig. 2**, a scanning laser **2** is featured with related microelectronics **3**, to guide the laser's beam onto the display screen **4**. The pixels **1** are arranged in a matrix array on the display screen such that the laser starts scanning the display screen from one corner, moving across horizontally until that line of pixels is scanned as a row. The laser locates the next pixel **6** below the first pixel **5** in the previous line scanned and proceeds to scan the entire row, completing the scanning of each row of pixels on the display screen **4** for one frame period. With further reference to the principal embodiment of the present invention, all pixels on the display screen are scanned once per frame period, with the intensity and or duration of the laser's beam on each pixel variable, in order to produce a variable depth of color on the display. For demonstration purposes, there may be 30 frames displayed on the screen **4** per second, hence the laser scans each pixel 30 times per second, once per frame period.

In a further embodiment of the present invention, the laser **2** scans all pixels on the display screen as described in the principle embodiment many times per frame period, for each frame. The significance of this method will be described later on.

In another embodiment of the invention, a projector may be used to project an image onto the display screen **4**, which is then enhanced by elements in the screen's construction, thereby replacing the laser **2**. Thus, the screen acts as a light amplifier in this application.

With reference to **Fig. 3**, this particular embodiment of the present invention basically discloses each pixel comprised of a photocell or photodiode **7** connected to a LED **8** in the presence of an applied electric field. The laser's beam **9** is directed at photodiodes **7** at each pixel location which generate a current in the form of electron-hole pairs, flowing to the connected LED **8** producing a color light output. The intensity and duration of the laser's beam on each photodiode is proportional to the LED's light output. When a light photon from the laser strikes an atom in the crystal lattice in the photodiode, it dislodges an electron. In this way an electron-hole pair is generated. The hole and electron will then migrate in opposite directions under the action of the electric field, and a small current can be seen to flow. The size of the current is proportional to the amount of light entering the photodiode **7**. The more light, the greater the numbers of electron-hole pairs that are generated, and the greater the current flow. By arranging the LEDs **8** of pixels within the display screen **4** in groups or patterns of red, green and blue with each group or pattern repeating itself comprising a matrix array, it is possible to create an RGB color display as illustrated in **Fig. 4**. Hence, by varying the laser's intensity and or duration on each photodiode **7** connected to each red, green and blue LED **8** of each pixel, a color display is generated on the screen **4**.

In another embodiment of the invention, with reference to **Fig. 5**, the display device comprises a sandwich type construction, which is primarily

a photocell **15** and LED **16** combination, whereby an electric field **17** is applied to the device, which will enhance the current flow once started. At one end, the n-p barrier **18** is highly reversed biased and this assists more electrons migrating across or in the avalanche effect as a result of the applied electric field. Consequently, this portion of the device acts as a photocell **15**. The opposite end acts as an LED **16** which is highly forward biased at the p-n barrier **19**, attracting more electrons flowing to it, thus enhancing the current flow. As the scanning laser's light particles or photons strike the photocell region near the barrier **18**, it can strike an atom in the crystal lattice and dislodge an electron. In this way a hole-electron pair or carrier is generated which will then migrate under the action of the electric field across the barriers **18** and **19**, and recombines with other electrons and holes to generate a light output from the LED **16**. In another embodiment, the carrier may also be a hole or an electron. With the applied electric field **17** in the region of the reverse biased n-p barrier **18**, a photo-generated hole or electron can collide with adjacent electron-bonding atoms, breaking the bond, and creating an electron-hole pair through this process of impact ionization. These newly created pairs can gain enough energy from the electric field **17** to cause further impact ionization until finally an avalanche of carriers is produced, increasing the current flow to the LED **16** producing a high intensity output. With a quantum efficiency greater than one, it is possible to have more than one electron generated for each photon of incident light yielding this high intensity output. With further reference to **Fig. 6**, as the beam **9** from the laser **2** is directed to strike the screen **4** near the reversed biased barrier **18**, electron-hole pairs have a mobility which is higher in direction **32** (perpendicular to display surface **34**) compared with direction **33**. Hence, electron-hole pairs do not disperse in all directions to produce a large pixel or dot **31** on the display surface **34**. Thus, a small concentrated laser

beam would yield a small pixel or dot **31** on the display surface **34**, and would have no effect on adjacent pixels or dots. Since the display screen **4** would be comprised of semiconductor material, the surface on which the laser's beam **9** first strikes bears properties that do not promote the spreading or dispersion of the laser's beam. These factors yield a high-resolution display device. As the scanning laser's light particles or photons strike the display screen **4** in the photocell region near the barrier **18**, a hole-electron pair is generated whereby either the hole or electron migrates under the action of the electric field across the barriers **18** and **19**, and recombines at location **35** to generate a light output at the LED region, displayed at location **31** on the display surface **34**. This display construction or system has a capacitance which when the laser's beam is applied, a large number of carriers (which are electron-hole pairs) are generated proportionally. Thus, more carriers generated means more light output from the LED region. With this capacitance in the system, the carriers continue to move and recombine even after the laser's beam is shut off, thereby improving the efficiency of the system, as explained later on.

In another embodiment of the invention, the electric field can be manipulated to control the on-off cycles of pixels in the display screen, as illustrated in **Fig. 7**. With the electric field applied, the laser is directed at a selected photocell and turned on at **22** then off at **23** (the laser's on-off cycle), during which time a capacitance or charge is built up in the photocell region **15 (Fig. 5)**. This produces a steady flow of current from duration **20** to **21** which illuminates the LED's, at which time **21** the electric field is turned off to complete a single frame of the display. Throughout duration **20** to **21** the LED's output will be at its maximum. At the end of every frame **21**, the electric field is shut off for every pixel then turned back

on prior to the scanning laser passing over each photodiode for the subsequent frame. Once the electric field is turned off **21**, the LED's output drops rapidly to zero **24**, as there is no longer the energy in the system to produce substantial quantum efficiency for a sustained LED output. This cycle repeats itself in subsequent frames for all pixels on the display screen **4** to have their connected LED regions illuminated. The reason for turning off the electric field is primarily due to the effect of residual capacitance in the system. The laser is applied for a very short duration compared to that of each frame period, and each time the electric field is shut off is because of this capacitance in the system. This capacitance may cause the light to take a while to decay off, thus to remove this the effect of residual capacitance in the system and to immediately shut off all light for any frame period, the electric field **17** must be shut off or shorted as further explained by **Fig. 13**. The photocell **15** and LED **16** combination with respective electrodes **47** & **48** are in the presence of an electric field **17**. By shorting the two electrodes together or by grounding one or both electrodes, the residual capacitance in the system may be instantly removed and all light immediately shut off. This is required for each frame displayed. Another reason for shorting the two electrodes together or by grounding one or both electrodes is to remove the feedback loop generated between the LED **16** and photocell **15**, as light from the LED produces more current flow from the photocell.

In another embodiment of the invention which refers further to **Fig. 8**, the electric field is manipulated to turn the LED's on and off for each frame period, utilizing a memory effect within the photocell region **15 (Fig. 5)** of the device. As the laser scans selected photocell regions **15** on the display screen **4** throughout duration **25** to **26** (the laser's on-off cycle), there is a charge or capacitance buildup and carriers or electron-hole pairs

move in all directions away from and towards the n-p barrier **18**, even after the laser beam is turned off. The movement of these electron-hole pairs in the presence of the charge or capacitance buildup is of sufficient energy to keep them in motion or to continue generation of new electron-hole pairs for the duration the external electric field is turned off, hence creating a memory effect. Once the electric field is turned on at **27**, the electron-hole pairs accelerate and migrate across the n-p barrier **18** with sufficient energy creating a current flow, thus turning on the LED's to maximum illumination. Cutting off the electric field at **28** would reduce the quantum efficiency of the device, turning off the LED's thus ending that particular frame at **28**.

In another embodiment of the present invention, with reference to **Fig. 11**, the laser **2** emits a beam **9** onto the display **4** whereby carriers are generated and light is emitted in all directions. As the scanning laser's light particles or photons strike the display screen **4** in the photocell region **42** the carriers are generated which will then migrate under the action of the electric field across the barriers **18** and **19**, and recombine with other carriers at location **43** to generate a light output at the LED region **44**. However, light that is generated travels in all directions and also strikes the display screen **4** in the photocell region **42**, thus more carriers are generated and a feedback loop is created for producing carriers. Since the LED output is proportional to the number of carriers generated, this method efficiently creates a high intensity output from the process started by the laser **2**. The LED output is sustained until the electric field is shut off near the end of each frame period, and the electric field resumed prior to starting the next frame. With further reference to **Fig. 12**, the electric field is at full strength at the beginning of each frame period, and consequently the generated carriers migrate to produce a light output

sustained at maximum output until the electric field is shut off at **45**, whereby almost immediately after, the LED output drops from maximum at **46** down to zero at the end of each frame.

In another embodiment of the present invention, the light does not travel in all directions to generate the feedback loop. The capacitance in the system is sufficient to keep the light illuminated for each frame period. To prevent the light from travelling back from the LED to the photocell region to generate the feedback loop, there is an optical barrier **49** (**Fig. 11**) which blocks all light waves from reaching the photocell region **42**.

In a further embodiment of the present invention, with the aid of **Fig. 9**, each pixel is addressed many times per frame as the laser scans each pixel on the display. This method is particularly useful in instances where the capacitance in the system may not have the efficiency to sustain the LED output for the entire duration of each frame. As the laser is applied to a particular pixel location, the LED output would quickly reach its maximum or peak value. Hence, for the first frame to be displayed, as the laser hits the display screen the LED output at a particular pixel rapidly reaches it maximum value **36**. Each time the LED output for that particular pixel drops to level **37**, the laser would address the same pixel again for the LED output to reach its maximum value. This process cycles many times per frame, with the laser addressing all pixels on the display between the time at **36** and **37**. In such instances where the capacitance in the system may not have the efficiency to sustain the LED output for the entire duration of each frame, the LED output for a particular pixel may rapidly drop to zero **38** and would not last for each frame period, significantly affecting the quality of display. Hence, the laser **2** addresses all pixels on the display screen **4** multiple times per frame period.

In another embodiment of the invention, with reference to **Fig. 10**, the display screen is comprised of a single color monolithic construction display device **40** onto which another screen **39** comprising patterned red, green and blue phosphors is placed. This being significantly different from the screen construction of **Fig. 4**, operates in a similar fashion as described in previous embodiments, with a single color output from each pixel on the monolithic display device **40**, which is primarily a photocell **15** and LED **16** combination, with an applied electric field **17**. Hence, the monolithic display device emits the same color light at pixels where the laser's beam hits the display screen **40**, and this light is directed to screen **39** comprising patterned red, green and blue phosphors which absorb the same color light and re-emits the light of a different color depending on which color (red, green or blue) phosphor is in front it. Hence a color display device is constructed from a monolithic light source combined with a matrix array of a patterned red, green and blue phosphor layer, and is presented to the user **41** who views the display device on the opposite side as the laser **2**.